Optimal Portfolio Methodology
for Assessing
Distributed Energy Resources Benefits
for the
Energynet™

California Energy Commission

IEPR Committee Workshop

Distribution Planning and the Role of DER

April, 2005

PIER Projects 500-01-039 and 500-04-008

Development Objectives

- **Fully incorporate DER in delivery system planning.**
- **A systematic methodology to determine the location, size, and characteristics of DER projects that enhance the performance of a power delivery network.**
- **Quantify the network benefits of these projects.**
- **Assess the merits of wires and nonwires (DER) network upgrade alternatives on a consistent basis.**

Network Operator Perspectives

- **How is network performance at the distribution level, and how does it affect/is it affected by the overall network?**
- **How might redispatch of existing resources improve network performance?**
- **What is the potential of DR and DG, especially in the distribution system, as measures for network performance improvement? How do they compare to transmission upgrades?**
- **What are the location and operating characteristics of DR and DG required to achieve these benefits?**

Certain features U.S. Pat. Pend.

What's Different

- **Transmission and distribution systems as a single, integrated power delivery network (Energynet dataset).**
- **Demand response, distributed generation, and capacitors as available DER options.**
- **A variety of measures to capture overall network performance.**
- **Individual dispatch of DER, coordinated for network benefits.**
- **AEMPFAST™ to determine individual network locations benefiting from resource additions.**
- **Potential network performance improvement from hypothetical "Optimal" DER Portfolio.**

Certain features U.S. Pat. Pend.

Development Conclusions

- **Analysis of integrated power delivery network (Energynet dataset) provides insights that are otherwise unavailable.**
- **Demand response, local generation, and capacitors can provide significant network benefits if they are the right size and in the right location, and their operation is coordinated.**
  - Benefits are not limited to Summer Peak conditions.
- **DER projects may yield comparable or superior network performance relative to conventional network upgrades.**
- **Actual results are characteristic of each network.**

Certain features U.S. Pat. Pend.

Integration of Energynet Dataset

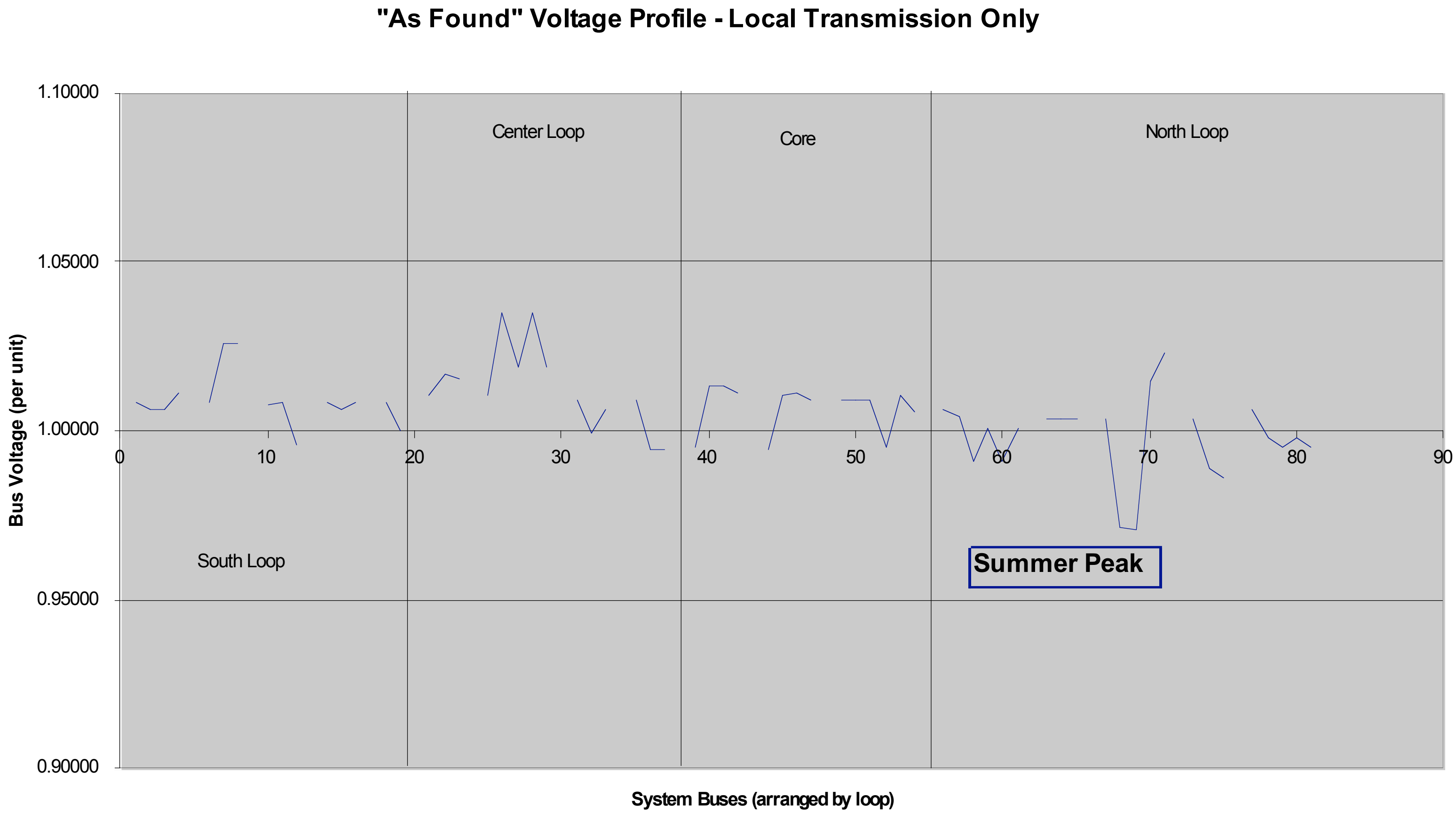
- **High-voltage transmission historically analyzed without connected distribution:**
  - WECC regional transmission characterization:
    - 2 115 kV transmission buses
    - Load split between two buses
    - 2 generators (plus two emergency peaksers)
  - Utility local system characterization:
    - 80 transmission buses (115, 60 kV)
    - Generators modeled as negative load
    - 28 load-serving buses, usually 60/12 kV stepdown transformer banks
    - No depiction of surrounding system

- **Distribution historically analyzed as individual radial feeders**
  - Networking branches connecting feeders often not modeled.

- **Final Energynet Integrated Dataset:**
  - Our characterization:
    - ~ 850 buses – 115 and 60 kV local transmission and 12 kV distribution
    - 48 12kV distribution feeders; 106 switchable branches interconnecting feeders
    - 422 customer load sites: 374 utility customer transformers, 43 customer-owned transformers
    - 6 existing generation units, 100 switchable capacitors
    - Fully-integrated into ~13,000 bus WECC west-wide high-voltage transmission model.

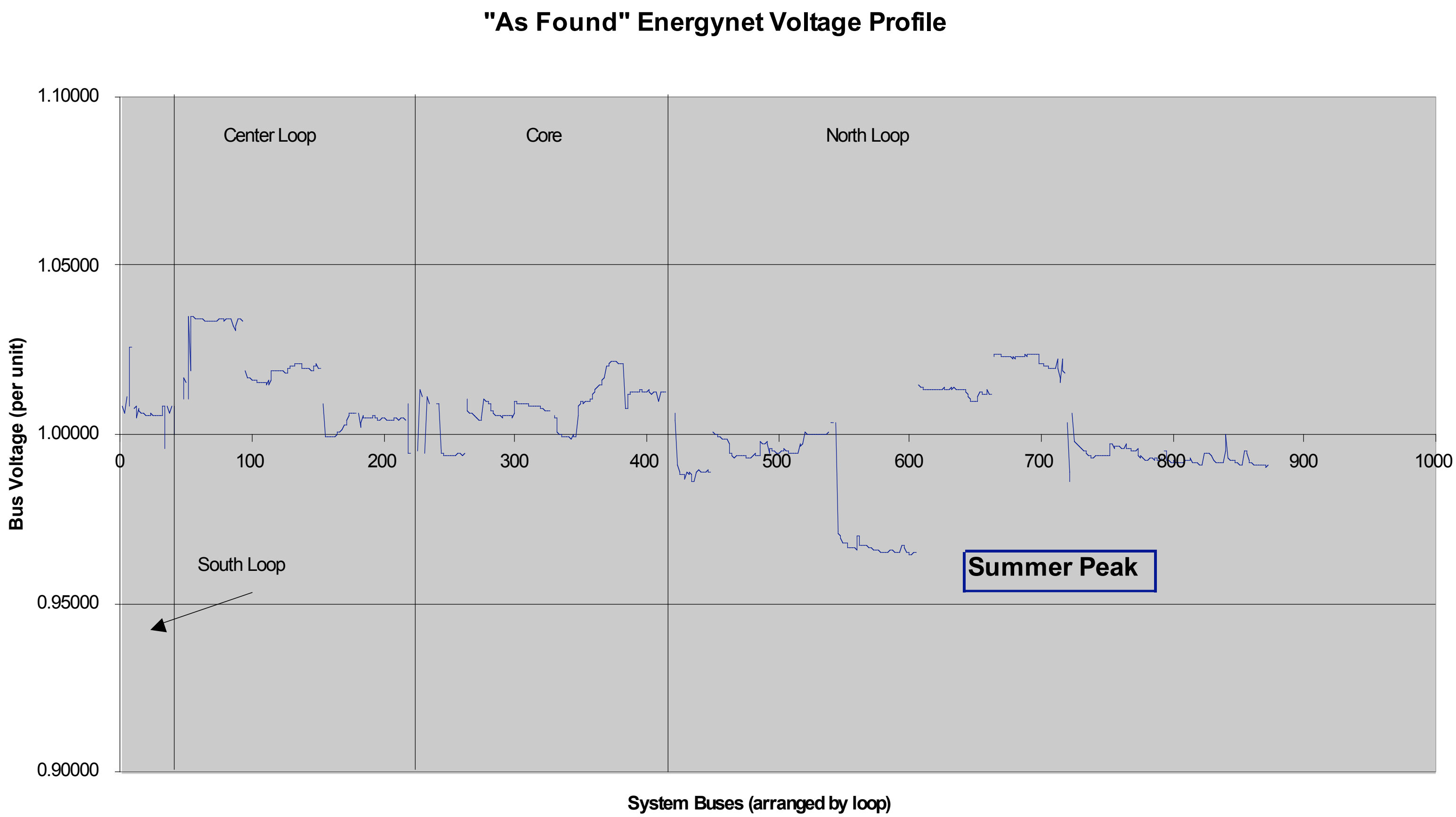
- **This project marks the first time an integrated power delivery model has been created.**

Local Transmission Voltage Profile



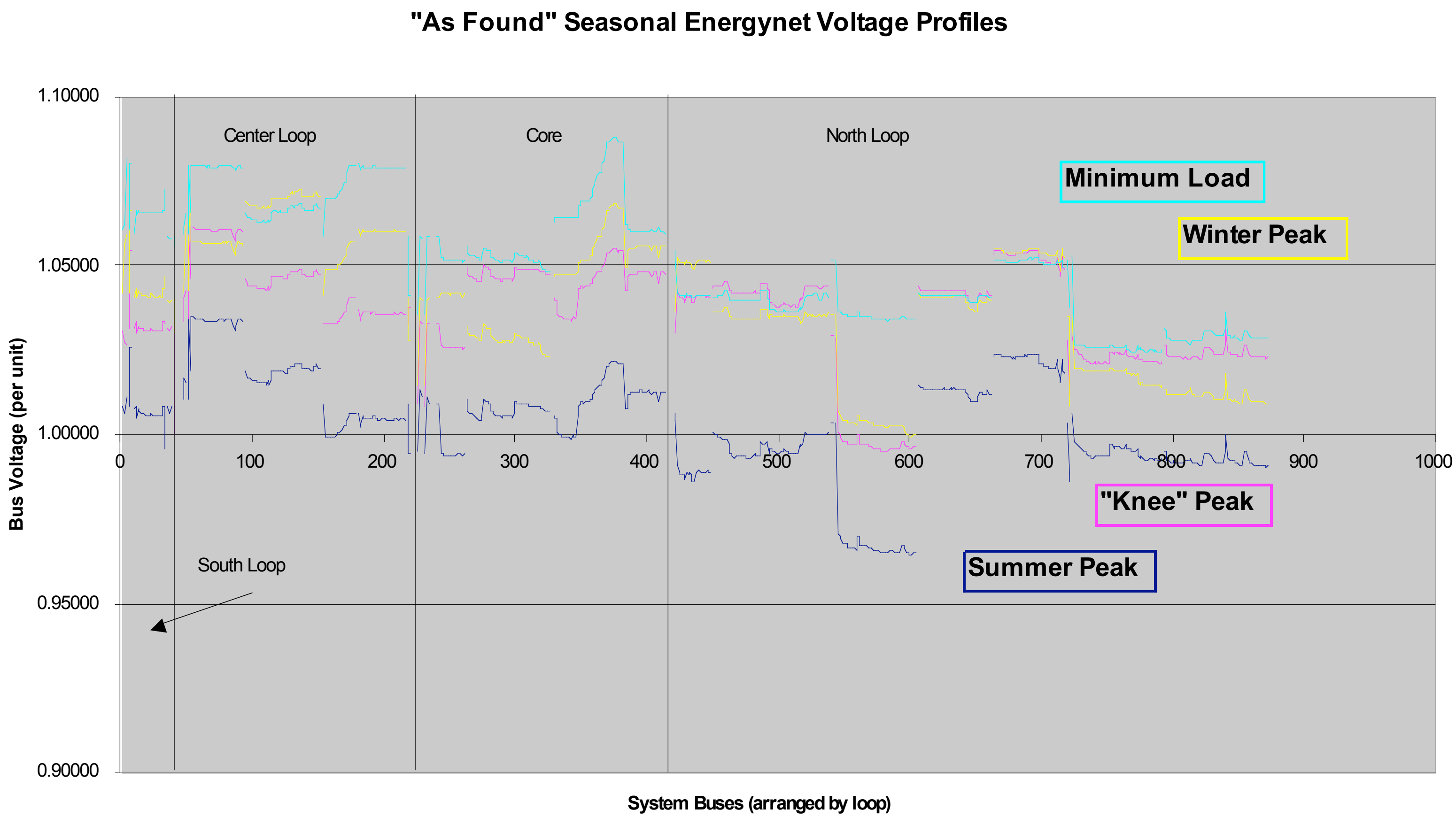
- All buses within +/- 5% of rated voltage under Summer Peak conditions– a healthy system.
- Customer-sponsored generation and demand response would not be connected at these buses.
- Distribution-level DER impacts invisible.

Integrated T&D



- Far more detail.
- Integrating distribution identifies more low-voltage buses and voltage variability.
- Impact of distribution changes immediately visible network-wide.

Seasonal View Using Recorded Network Data



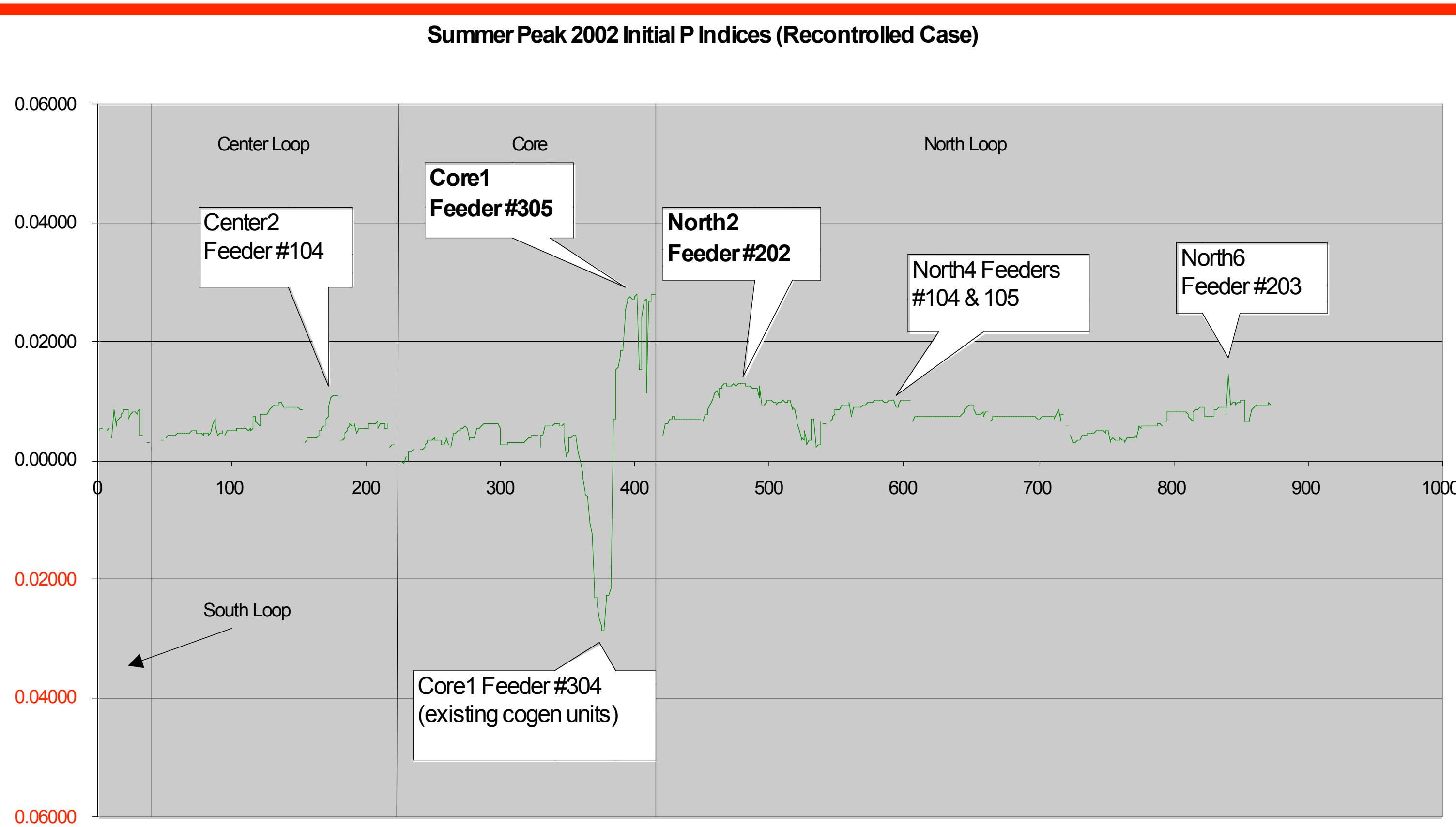
– Actual loads reveal seasonally-varying network conditions.

– "1% highest hour" Summer Peak actually atypical.

Improving Delivery Network Performance

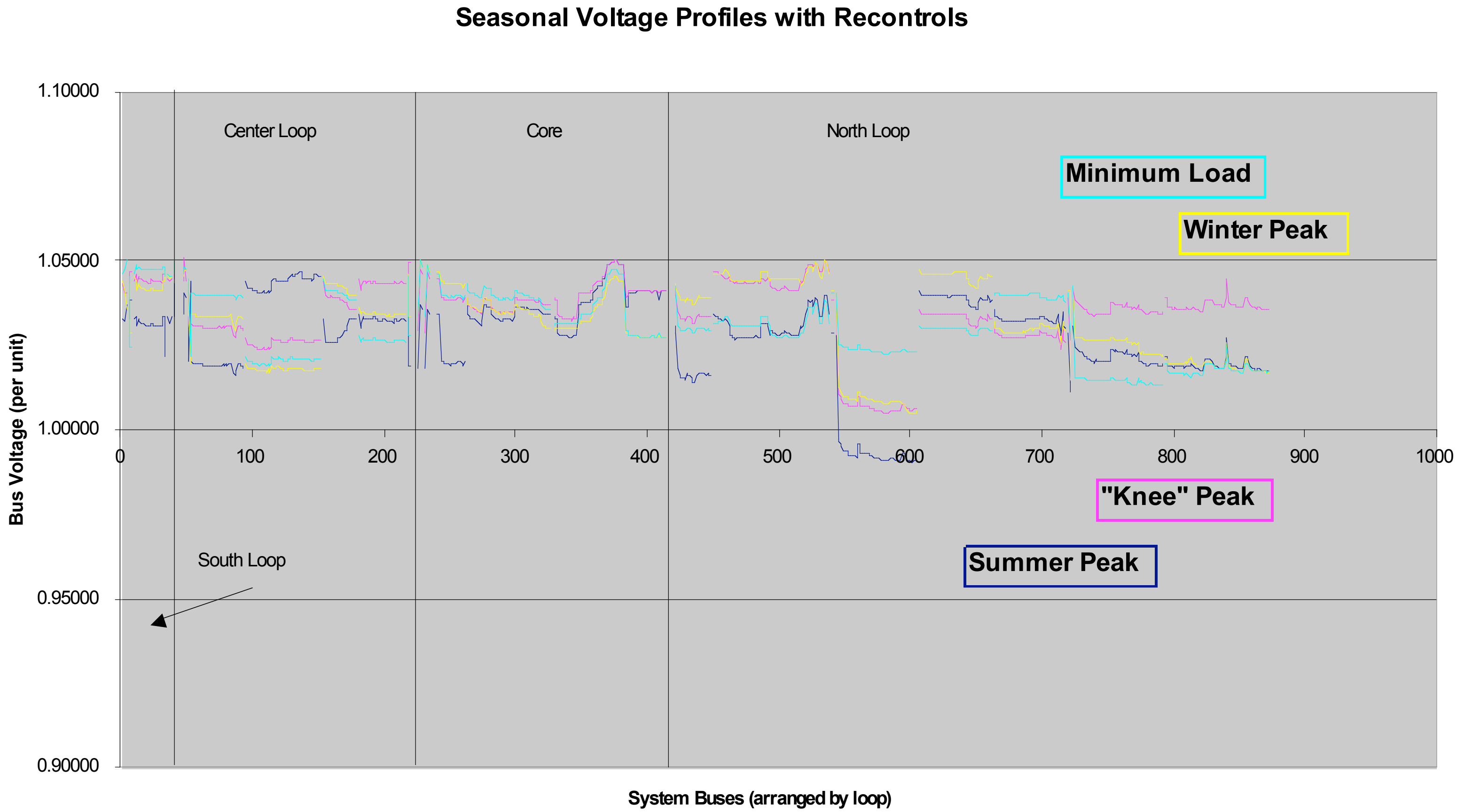
- **Objective:**
  - Minimize real power losses, reactive power consumption, and voltage variability with a target voltage of 1.05 PU.
- **Existing Controls:**
  - Set MVAR output from shunts and MW and MVAR output from existing embedded generation for the best overall network performance.
- **Reactive Capacity Additions (MVAR)**
  - Station capacitors and line capacitors in standard sizes.
- **Dispatchable Demand Response Additions (negative real and reactive load)**
  - > 200 kVA customers
  - Limited to 2-15% of customer load depending on customer size and case.
- **Distributed Generation Additions (MW + MVAR based on synchronous generator pf range)**
  - Limited to 60% of customer load
  - Non-export feeder limits.

Redispatching and Adding Resources Using AEMPFAST™



- P Index identifies individual network locations where adding P resource is the most beneficial for the "objective" of improved overall network performance.
- Hundreds of potential DER sites ranked in terms of their network benefits.

Redistributing reactive sources improves voltage profiles.



- Integrated network model reveals impacts of individual distribution-installed capacitors.
- AEMPFAST results specify optimized operational settings.
- Localized changes have network-wide impacts.

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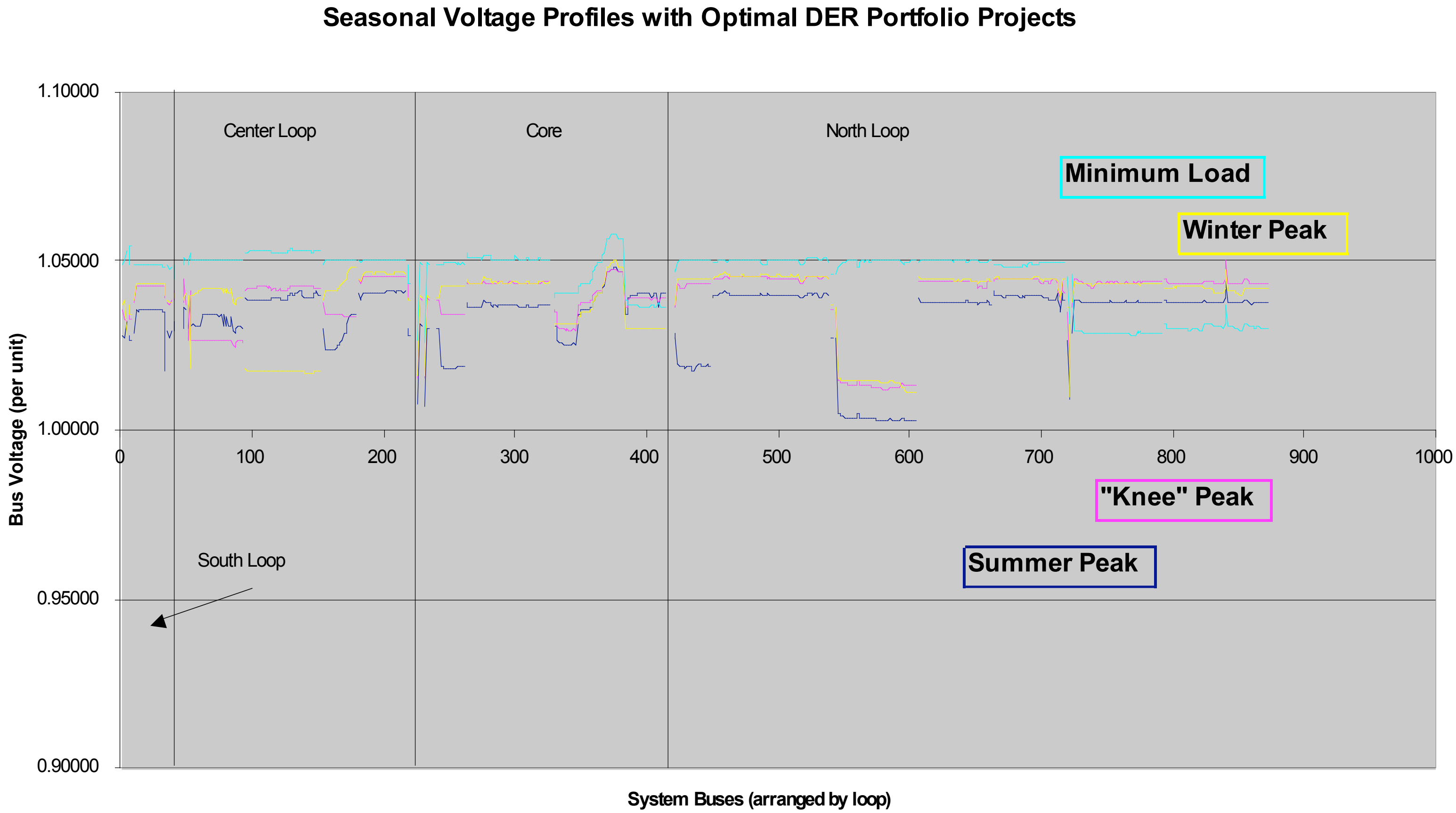
Optimal DER Portfolio projects yield significant improvement.



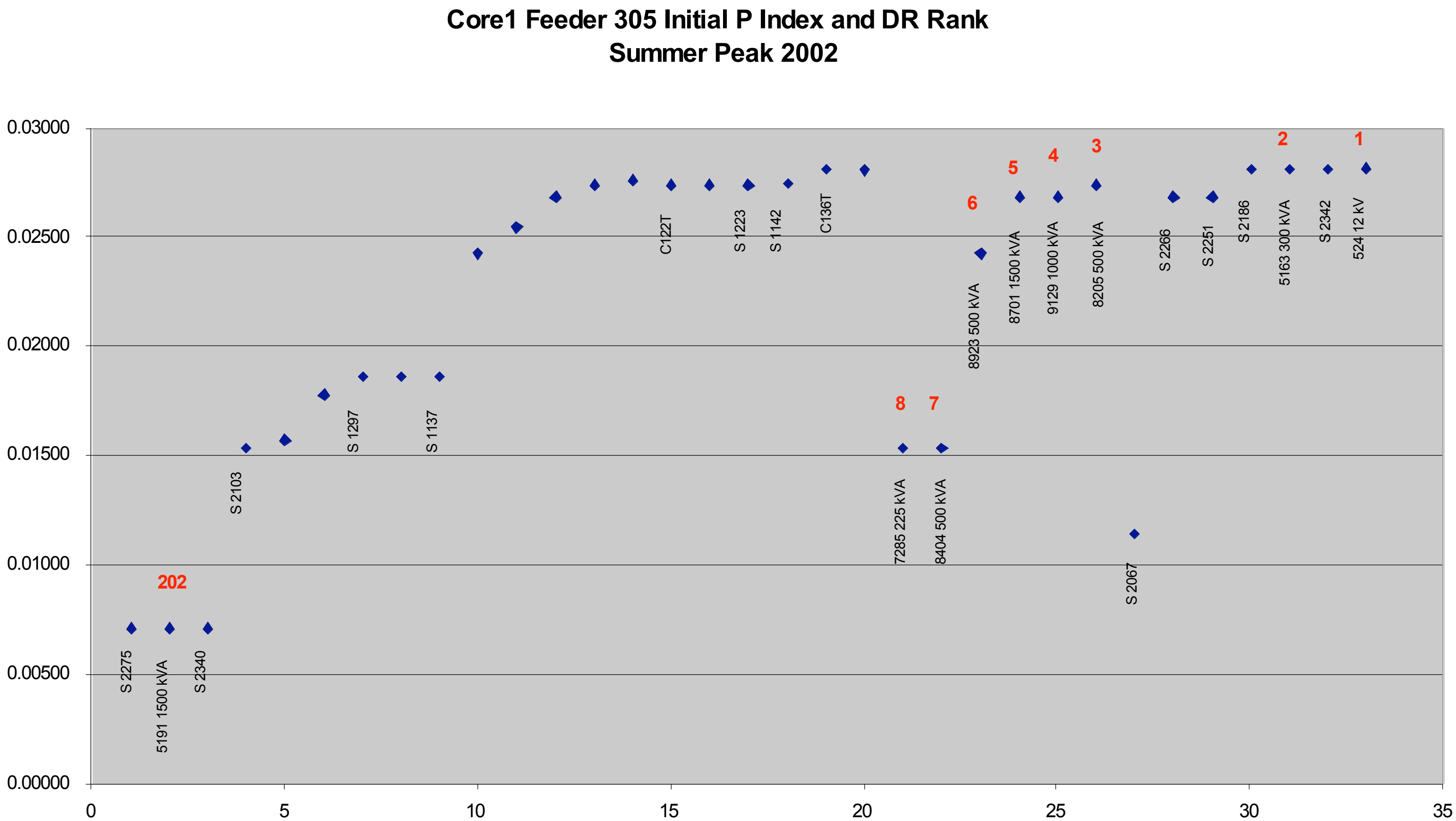
- Portfolio of DR and DG projects with specified locations, sizes, seasonal operating profiles.
- Individual projects ranked in terms of network value under each set of conditions.

Key Locations

- **Summer Peak 2002 highest-ranked DG additions (Light Load Limit case):**

Location		Buses/Sites	Total DG (kW)	Avg Rank
North2	Feeder 202	5	1,070	11
Center2	Feeder 104	1	305	14
Core1	Feeder 305	9	287	15
North4	Feeder 105	6	860	43
North6	Feeder 203	10	1,481	44
North2	Feeder 204	1	1,341	53
North4	Feeder 104	21	1,162	53
North4	Feeder 304	1	130	56
North4	Feeder 204	1	690	59
North4	Feeder 101	6	869	62
Center3	Feeder 303	11	1,864	63
North2	Feeder 203	13	2,132	65
North4	Feeder 203	4	1,059	69
North4	Feeder 205	1	545	69
North6	Feeder 205	4	608	78
North6	Feeder 201	6	905	86
North4	Feeder 305	1	520	87
North6	Feeder 202	4	240	92
South3	Feeder 104	12	1,485	102
North4	Feeder 303	1	136	102
North4	Feeder 201	1	33	107
Center3	Feeder 203	1	850	111
North4	Feeder 103	1	530	120
North2	Feeder 102	1	695	121
North4	Feeder 301	11	880	122
North4	Feeder 202	1	125	132

Locations on Feeder Matter



- High-ranked DER sites indicated by high P indices.
- High-ranked sites electrically distant from substation.

Characteristics of Individual Projects

- **Core1 Feeder 305 DR Projects (2002 Dispatch)**

BUS#	Customer Class	Summer Peak DR (%)	Knee Peak DR (%)	Winter Peak DR (%)	Minimum Load DR (%)
524	Over 1,000 kVA	15%	5%	2%	2%
5163	200-1,000 kVA	15%	2%	2%	2%
8205	200-1,000 kVA	15%	2%	2%	2%
9129	200-1,000 kVA	15%	2%	2%	2%
8701	Over 1,000 kVA	15%	5%	2%	2%
8923	200-1,000 kVA	15%	2%	2%	2%
8404	200-1,000 kVA	15%	2%	2%	2%
7285	200-1,000 kVA	15%	2%	2%	2%
5191	Over 1,000 kVA	15%	2%	2%	2%

- **Core1 Feeder 305 DG Projects (2002 Dispatch)**

BUS#	Customer Class	Summer Peak DG (kW)	Knee Peak DG (kW)	Winter Peak DG (kW)	Minimum Load DG (kW)
524	Over 1,000 kVA	115	115	115	0
5163	200-1,000 kVA	8	8	8	0
8205	200-1,000 kVA	14	14	14	0
9129	200-1,000 kVA	29	29	29	0
8701	Over 1,000 kVA	43	43	43	0
8923	200-1,000 kVA	14	14	14	14
8404	200-1,000 kVA	14	14	14	14
7285	200-1,000 kVA	7	7	7	7
5191	Over 1,000 kVA	43	43	43	43

Local Network Benefits -- 2002 Optimal DER Portfolio

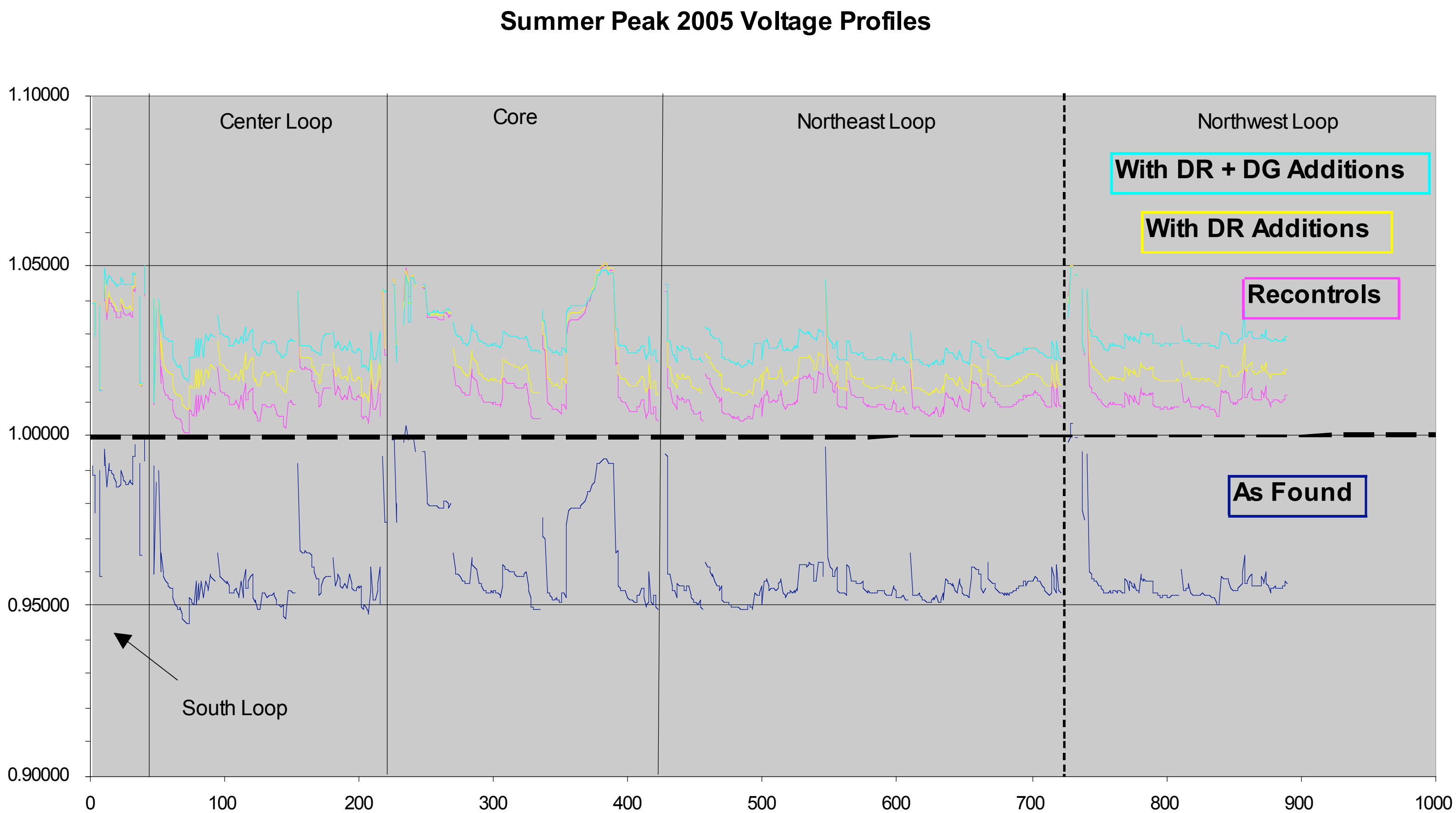
- **DER Portfolio Projects:**
  - DR: 389 sites; 10.5 MW (2.6% of load on-peak)
  - DG: 380 sites; 54.9 MW on-peak (13.8% of peak load).
    160 kW average, 8.9 MW largest.

- **Network Benefits:**
  - Loss reduction: Total of 6.7 MW, 85.4 MVAR on peak
    33 - 39% reduction in local real power losses.
    28 - 45% reduction in local reactive power losses.
  - Increased load-serving capability: 117.6 MW
  - Incremental peak capacity: 60.3 MW
  - Eliminated all low-voltage buses.
  - Reduced voltage variability

  ➢ **Network benefits occur under Winter Peak and Minimum Load conditions (i.e., not limited to Knee Peak and 1% highest hour Summer Peak).**

- **Estimated value of network benefits:**
  - ~$450 per kW of year-round dispatchable DER if capacity is included.

2005 Optimal DER Portfolio Network Benefits



– **Voltage profiles flatter; low-voltage corrected.**

Local Network Benefits -- 2005 Optimal DER Portfolio

- **DER Portfolio Projects:**
  - DR: 390 sites; 25.5 MW (2.6% of load on-peak)
  - DG: 149 sites; 66.7 MW on-peak (11.5% of peak load). 447 kW average, 14.3 MW largest

- **Network Benefits:**
  - Loss reduction: Total of 11.8 MW, 155.7 MVAR on peak
    40% reduction in local real losses.
    31% reduction in local reactive losses.
  - Increased load-serving capability: 46.7 MW
  - Incremental peak capacity: 104.0 MW
  - Eliminated all low-voltage buses.
  - Reduced voltage variability

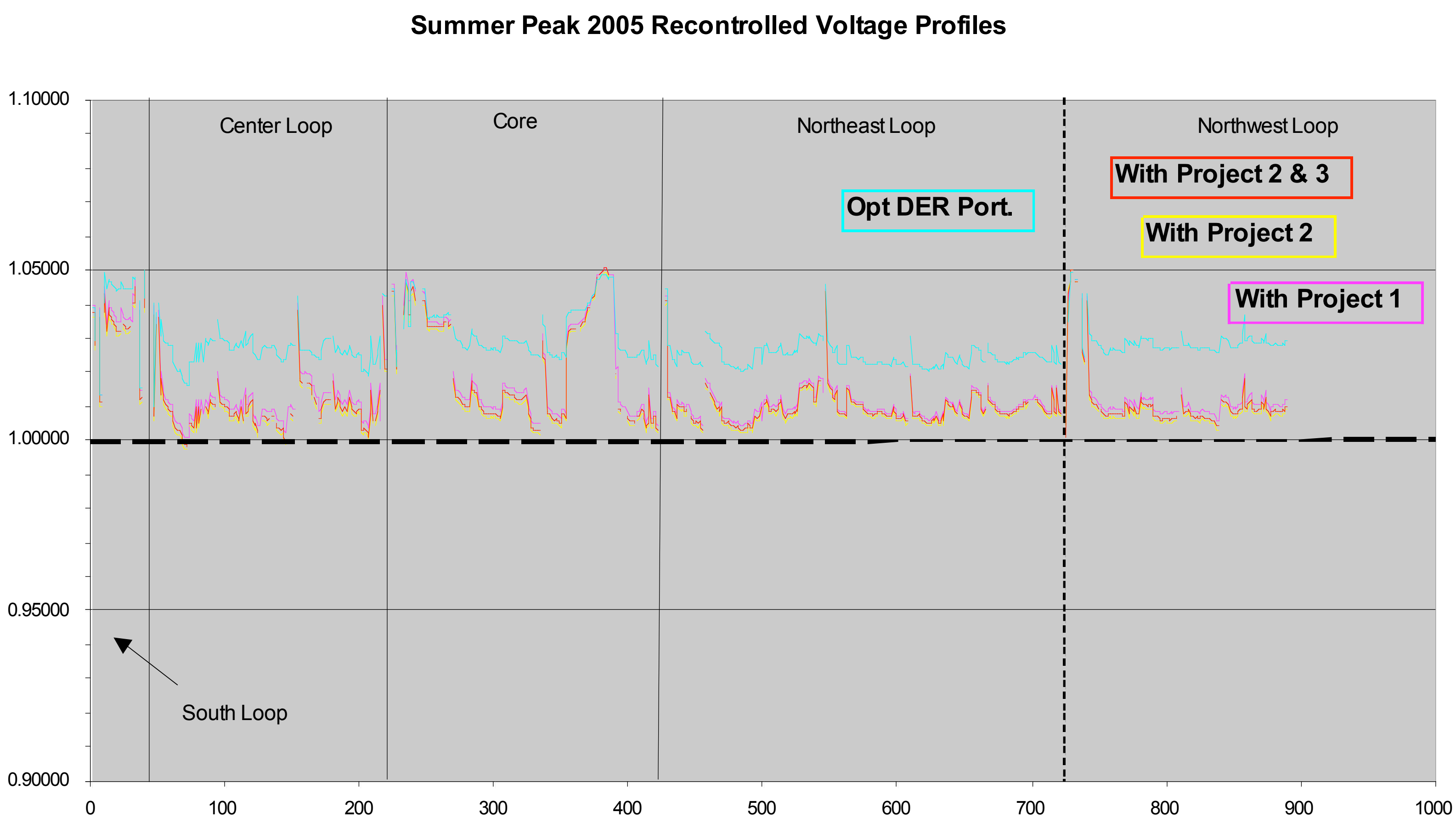
Illustrative Comparison with Conventional Network Upgrades

- **2005 Network Performance Impacts:**

	Optimal DER Portfolio	Project 2	Project 3	Projects 2&3
Incremental P Losses	**-40%**	**38%**	**-2.0%**	**18%**
Incremental Q Losses	**-31%**	**27%**	**-0.4%**	**21%**
Incremental Load-serving Capability (MW)	**46.7**	**37.5**	**38.5**	**79.0**
Incremental System Capacity (MW)	**104.0**	**-**	**147.1**	**147.1**

- **Potential DER network benefits are comparable to those of these network upgrade projects.**
- **Which alternative is "better" depends on costs, benefits other than network performance, and the system operator's objectives.**

Illustrative Comparison with Conventional Network Upgrades



– **Optimal DER Portfolio yields greater improvement in voltage profile.**

Recontrol of existing resources to improve network performance

- **Existing capacitor operating profiles:**
  - 64% of capacitors either change settings during one or more seasonal peak or change on-peak/off peak settings seasonally.
    - 18% change settings for “1% highest hour” summer peak
  - 46% operate in default positions during peak periods or shut off during minimum load periods year-round.

- **All existing embedded generators change MVAR dispatch under at least one set of modeled conditions.**

Promoting New Beneficial DER Projects

- **Requirements can be established ahead of time.**
  - Optimal DER Portfolio can be easily re-characterized as network evolves.
- **Availability requirements:**
  - About half of large customer DR projects are preferred locations for higher dispatch only during specified times of year.
  - Most valuable DR sites for 1% highest hour peak dispatch are identifiable.
  - 60% of DG projects do not need to vary MW output for system performance.
- **Contractual requirements:**
  - DR or DG project size located as specified; size comparable to study result.
  - Site-specific dispatchability requirements met; telecommunication infrastructure in place.
  - DG VAR output dispatchable by network operator within limits.
  - Rights to value of system capacity remain with network operator.
- **Projects in the right locations meeting these requirements could be paid a share of the value of the network benefits they will yield.**

PIER Project 500-01-039 Conclusions

- **DER with the right characteristics can improve network performance.**
- **Network benefits of DER can be quantified and valued and compared with traditional network upgrades.**
- **Ideal location, size, and dispatch of beneficial DER projects for a given network can be determined.**
  - Valuable information for network operators considering upgrades and to direct DR and DG programs.
- **Energynet dataset integrating transmission and distribution is practical and adds new insights.**
  - Potentially useful for a variety of network planning purposes.
- **AEMPFAST is a valid and useful tool within this application.**
- **Barriers remain for DER at high penetration levels.**

Elements of Next Phase (PIER Project 500-04-008)

- **Partnering with SCE, Navigant, DOE**
- **Major utility-scale Energynet datasets**
  - 15X size, more complex
  - Heavily-loaded/high growth
  - Networked transmission
- **Expand DER devices and measures considered.**
  - Storage devices
  - Changeable topology
- **Expand measures of network performance.**
  - Value of Service
  - Optimal Technologies' Reliability Optimization
  - Network operator planning objectives
- **Common cost-benefit evaluation for DER/nonwires and existing/traditional network measures.**
  - Using Navigant "Spending Prioritization Model" used by utilities to prioritize asset investments.
  - Puts optimization analysis and results in utility decisionmaking perspective
- **Field validation of modeled network characteristics and impacts.**

SCE Project Progress and Conclusions Thus Far

- **Two subject systems within SCE territory identified.**
  - Heavy demands on existing infrastructure.
  - Networked transmission.
- **More complex than anticipated.**
  - Longer feeders with more elements
  - Single-phase loads
- **Dataset integration a key challenge and opportunity**
  - Legacy data more accessible/extractable.
  - Value in automation.

Ties Between NPT Methodology and Navigant SPM

- **Map NPT results to Navigant SPM.**
- **Value "network benefits" for consideration in spending prioritization.**
  - $ value for some difficult-to-price benefits such as reliability, voltage profile improvement.
- **Summarize costs and benefits of DER as available measures for improving system infrastructure and performance.**
  - Impact on capital and operating budgets.
- **Navigant "funding curve" output incorporating both both wires and DER (or other non-wires) initiatives under a common cost/benefit evaluation methodology.**

Details

- **500-01-039 Project Participants**
  - New Power Technologies
  - Cupertino Electric, Inc.
  - Silicon Valley Power
  - Optimal Technologies (USA), Inc.
  - Rita Norton & Associates LLC
  - Silicon Valley Manufacturing Group
  - William M. Stephenson
  - Roy C. Skinner
  - Linda Kelly (CEC Project Manager)
  - Laurie Ten Hope (CEC Program Area Lead)

- **Technical Advisory Committee**
  - Dave Hawkins, California ISO
  - Marija Ilic, Carnegie Mellon
  - Jim Kavicky, Argonne National Lab
  - Don Kondoleon/Demy Bucaneg, CEC
  - John Monestario, PG&E Distribution Engineering (retired)

Details

- **500-04-008 Project Participants**
  - New Power Technologies
  - SCE
  - Navigant Consulting (funding through DOE/NETL)
  - Optimal Technologies (USA), Inc.
  - Cupertino Electric, Inc.
  - William M. Stephenson
  - Jeff Zias
  - Roy C. Skinner (projected)
  - Linda Kelly (CEC Project Manager)
  - Mark Rawson (CEC Distributed Energy Integration Research Program Manager)

About New Power Technologies

- **New Power Technologies identifies and develops businesses and technologies enabling a distributed, intelligent Energynet™ energy infrastructure:**
  - Integrated transmission and distribution
  - Embedded (or "distributed") generation with remote generation
  - Loads responsive to network conditions
  - Energy services mass customized to meet customer needs

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